

# Miombo LCLUC - LUC and Ecological Processes

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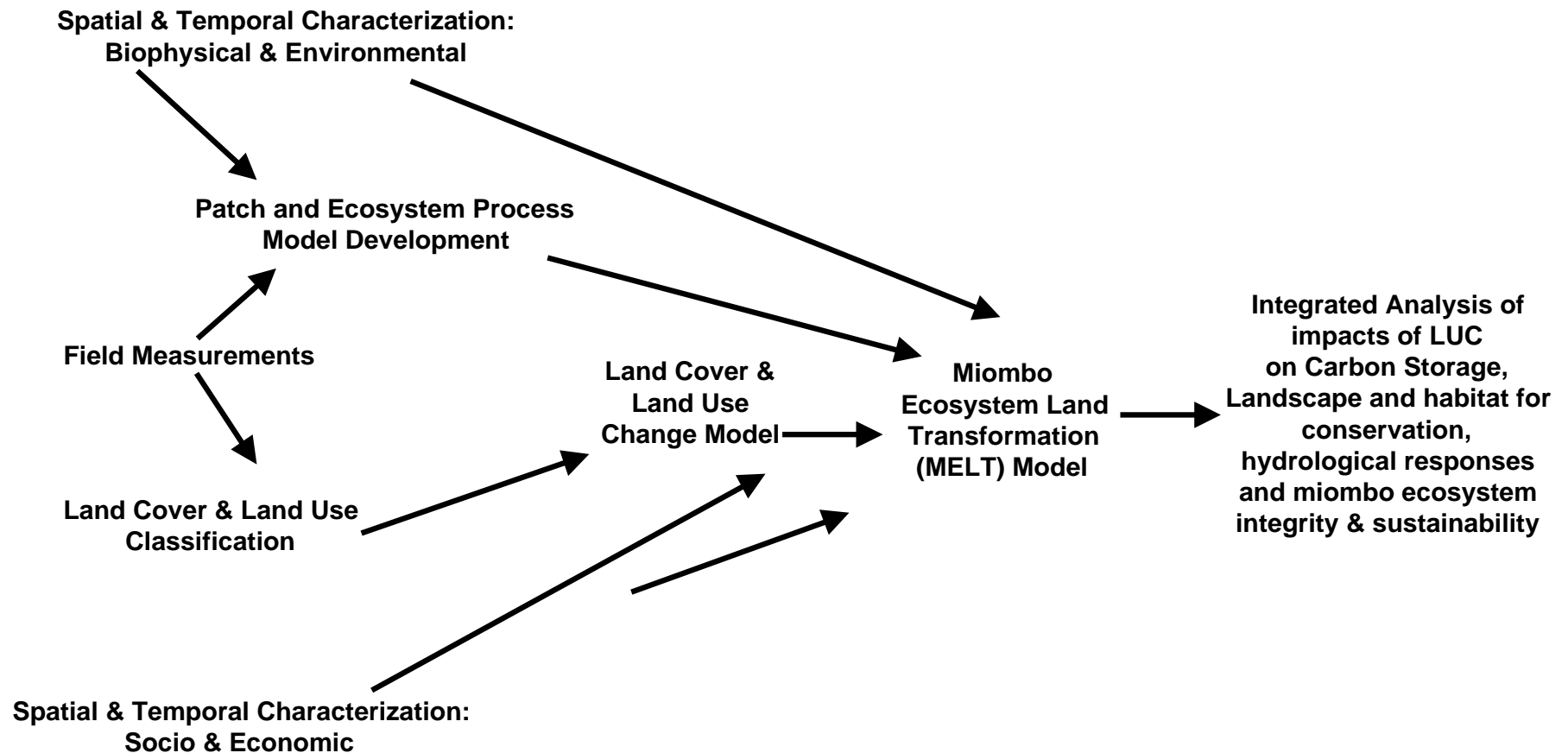
*Daniel Semwayo, University of Zimbabwe*



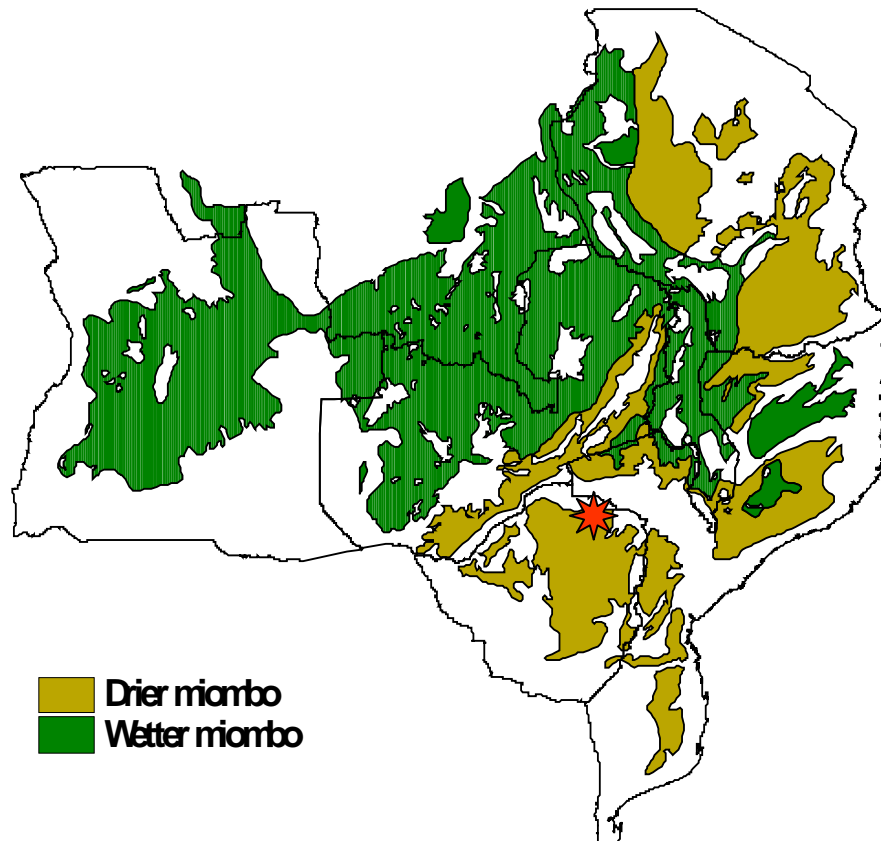
# Miombo NASA LCLUC Project Objectives

- To analyze land cover changes as driven by land use change in miombo ecosystems by *integrating* analyses of remotely sensed data, field measurements of land cover and land use attributes, and socio-economic drivers, at selected study sites in southern Central Africa;
- To develop an ecological model for miombo to evaluate effects of disturbance on vegetation development (including human induced disturbance such as fire, and use; and
- To develop an integrated model that couples miombo ecosystem dynamics with land use and socio-economic drivers

# The Miombo Ecosystem Land Transformation (MELT) Model: Linkages



# The Miombo Region and White (1983) Vegetation Types



# The Miombo Network

The Miombo Network is a regional alliance of researchers working on land use and land-use change in the miombo region of Central Africa, under the auspices of the IGBP/IHDP Land Use and Cover Change (LUCC) Project and the IHDP/IGBP/WCRP Global Change System for Analysis, research and Training (START)

Members in Africa include government, university and research institutions in DRC, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe. Elsewhere, members include Universities, research institutions and NGOs in the U.S., Europe and Australia.

Main sponsors include NASA, WWF, START, LUCC and DIS.

A joint science agenda was developed under the central theme of *land use and land-use changes* and their consequences, and is available as IGBP Report 41.

GLOBAL  
I G B P  
CHANGE

## IGBP REPORT 41

International Geosphere-Biosphere Programme (IGBP)



**The Miombo Network:  
Framework for a Terrestrial Transect Study of  
Land-Use and Land-Cover Change in the  
Miombo Ecosystems of Central Africa**

The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP) of the  
International Council of Scientific Unions (ICSU)  
Stockholm, Sweden

edited by: Desanker, Frost, Scholes, Justice  
(1997), Available from IGBP in Stockholm,  
START, or from the authors, can  
request via the Miombo Web Page at:

<http://miombo.gecp.virginia.edu>



## **Different States of Miombo from intact woodland to tree-grass mixtures, in response to fire**





## Rural populations depend on miombo for wood and construction





*Miombo Wood Used to Make Charcoal, Charcoal Transported to City for Sale*





*Woodland is Slashed and Burnt for Agriculture, Fields Coppice Profusely*

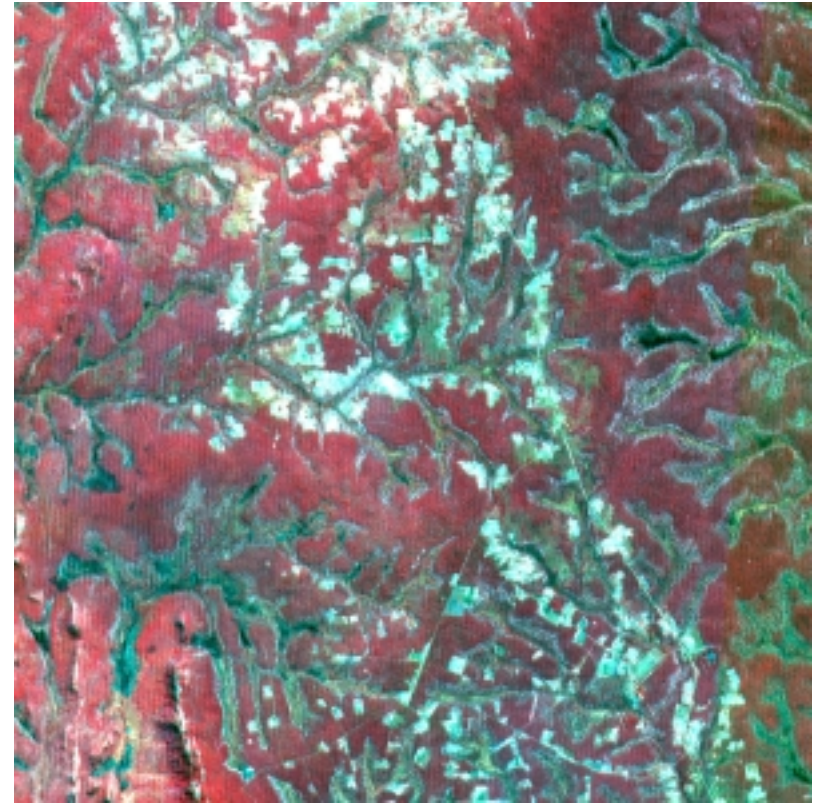




*Wood Sold for Firewood, Woodland Recovers if Abandoned*

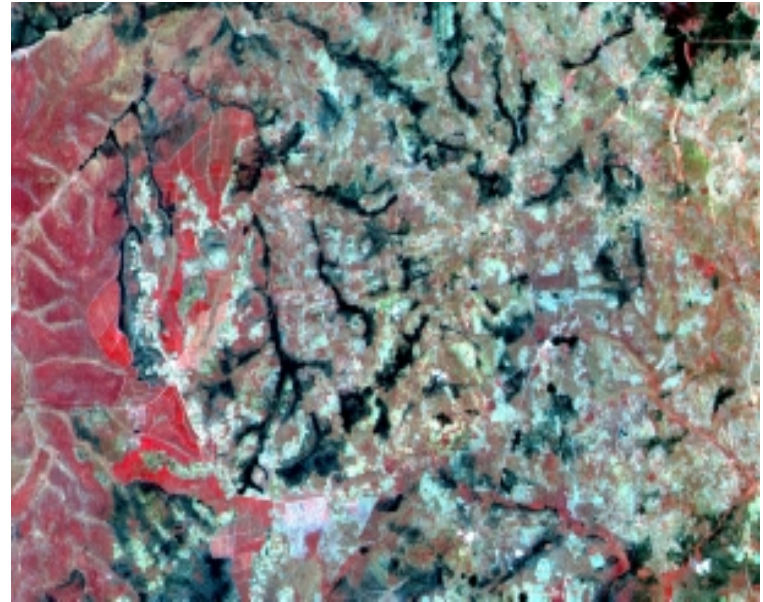
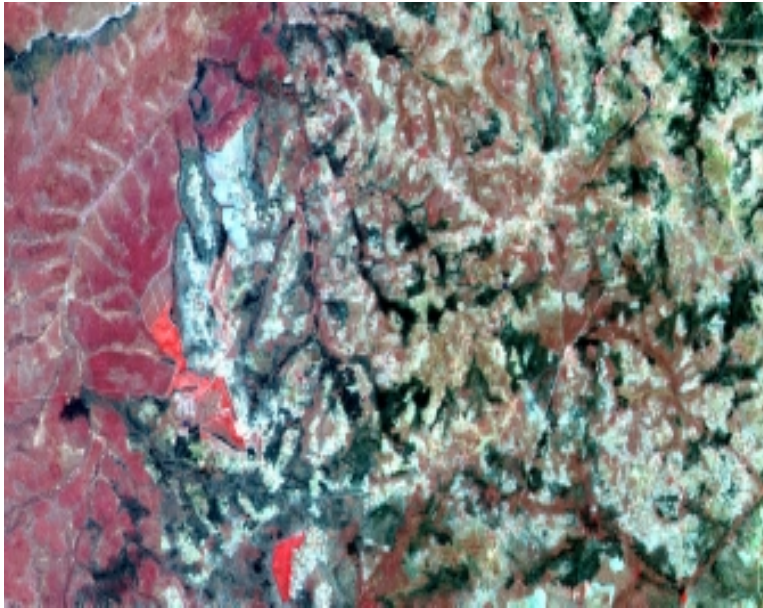






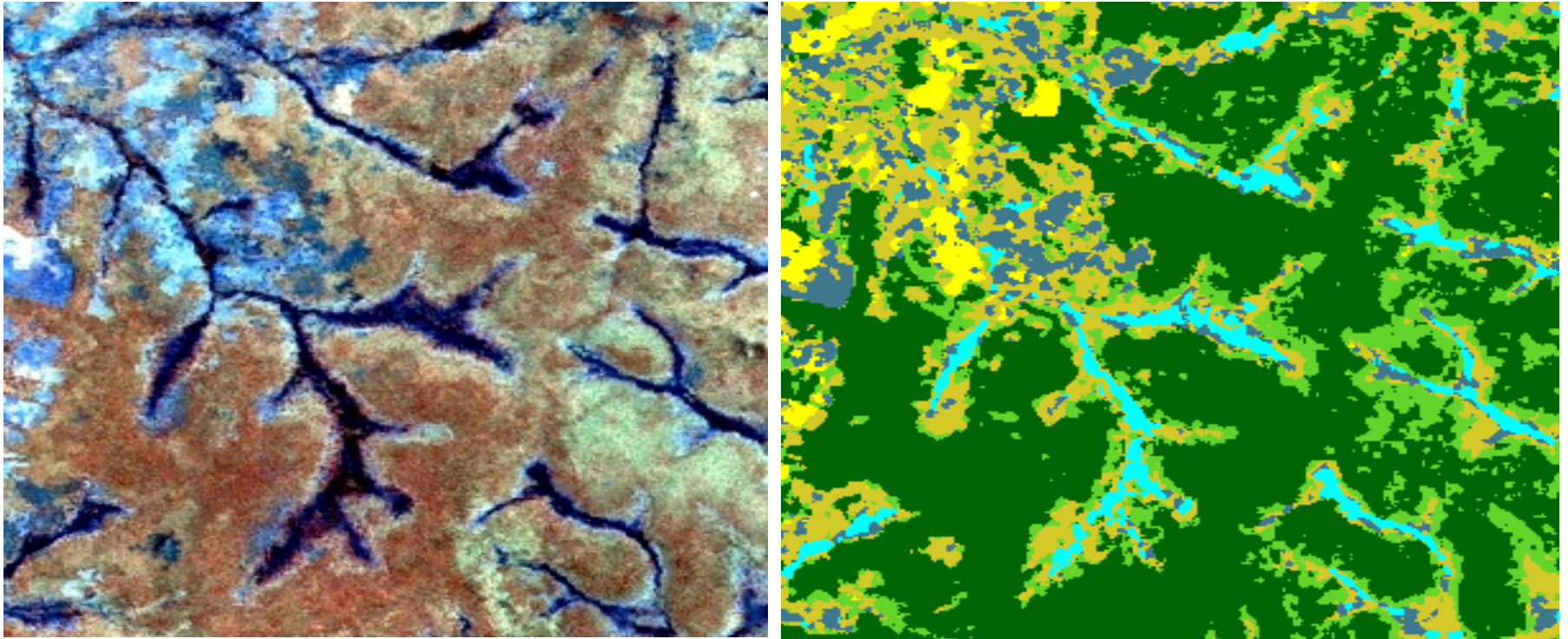
**Land cover changes in north east Zambia (Kasungu National Park -KNP, Malawi is on right), based on SPOT XS from Oct 1987 (late dry season) and June 1994 (cool and dryish). Notice typical dambo landscape, fire scars, and agricultural expansion with time. Also note very little encroachment in the KNP.**





**Kasungu, Malawi, 1987 (left), 1992 (right) - dry season images - lots of fires.  
This is in fire-cured tobacco area, notice forest reserve area intact on left**

**Landsat TM False color composite of Miombo Landscape showing  
Dambos and Burn Scars on left, classified image on right (Jaiteh  
method): woodland, grassland, water/scars, cultivated/bare**





Coppicing likely increases above ground biomass, below-ground components likely significant stores of biomass - regional impacts wrt Carbon stocks largely unknown



Baseline Land Cover/Land  
Use Maps - Historical -  
1990/1 - Harmonize national  
products into regional map



## ***Data Sources for Regional Mapping***

<b>Country</b>	<b>Data</b>
<b>Mozambique</b>	<b>Visual classification of 1992-93 Landsat TM supplemented with low-level aerial sampling. Completed 1995</b>
<b>Zimbabwe</b>	<b>Visual classification of Landsat TM, 1992-93. Intensive field inventory in 1995. Mapping Completed 1996</b>
<b>Malawi</b>	<b>Visual classification of 1991-92 Landsat TM with field checks in 1993.</b>
<b>Tanzania</b>	<b>Visual classification of 1992-93 Landsat TM. Mapping completed 1996.</b>
<b>Zambia, Angola</b>	<b><i>In progress – partial coverage available, may use new L7 to develop new maps or use 1 km products</i></b>

# Miombo Regional Classification System for Vegetated Land Covers (after Zimbabwe System)

<i>Canopy Cover</i>	<i>Height</i>			
	>15m	15-5m	5-1m	<1m
100-70%	Nat Forest			
100-70%	Forest	Forest	Forest	
	Plantation	Plantation	Plantation	
70-20%		Woodland	Bushland	
20 - 2%	Wooded	Wooded	Bushland	
	Grassland	Grassland	Savanna	
<2%	Grassland	Grassland	Grasland	

# UMD (DeFries et al.) and Miombo Regional Legends

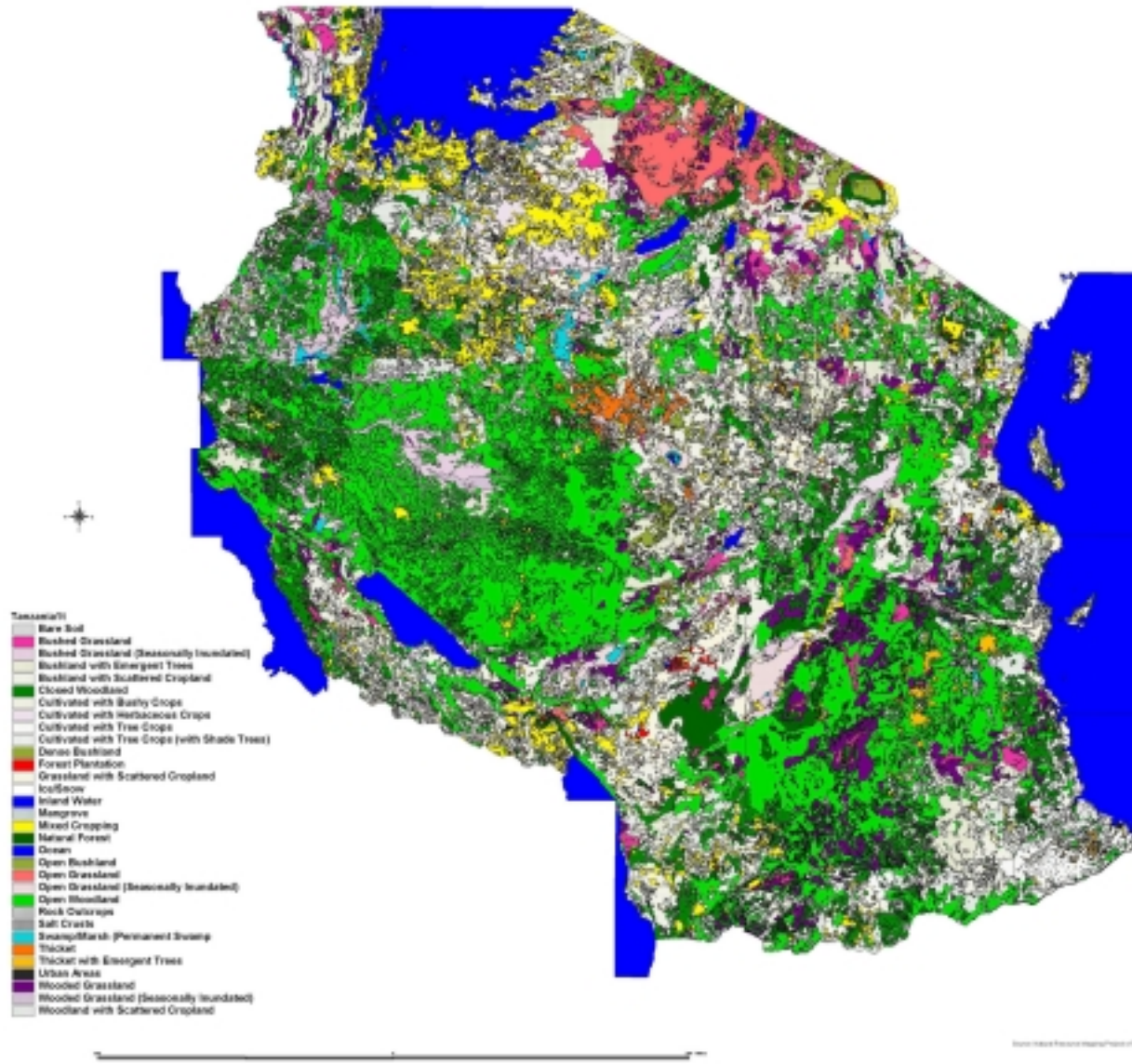
## UMD Classes

- 0 WATER (and Goode's interrupted space)
- 1 EVERGREEN NEEDLELEAF FOREST
- 2 EVERGREEN BROADLEAF FOREST
- 3 DECIDUOUS NEEDLELEAF FOREST
- 4 DECIDUOUS BROADLEAF FOREST
- 5 MIXED FOREST
- 6 WOODLAND
- 7 WOODED GRASSLAND
- 8 CLOSED SHRUBLAND
- 9 OPEN SHRUBLAND
- 10 GRASSLAND
- 11 CROPLAND
- 12 BARE GROUND
- 14 URBAN AND BUILT-UP

## Miombo Classes

- 1 Natural Forests
- 2. Plantations
- 3. Woodlands
- 4. Bushlands/thickets
- 5. Wooded grassland
- 6. Grassland/Dambos
- 7. Barren areas
- 8, Water
- 9. Swamps and Marshes
- 10. Cultivated Land
- 11 Builtup area

## Land Use and Land Cover Map of Tanzania



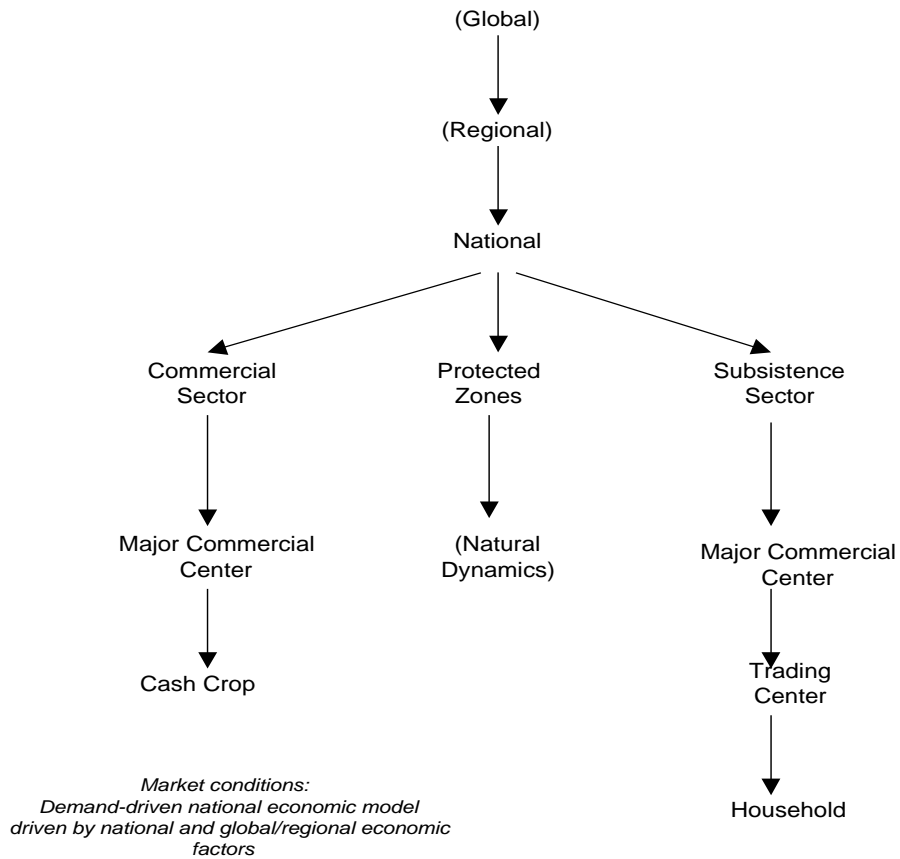


# **Image Classification and Patterns of Land Cover/Land Use**





Typical rural scene -  
settlements with trees,  
sacred grounds covered  
in dense woodlands

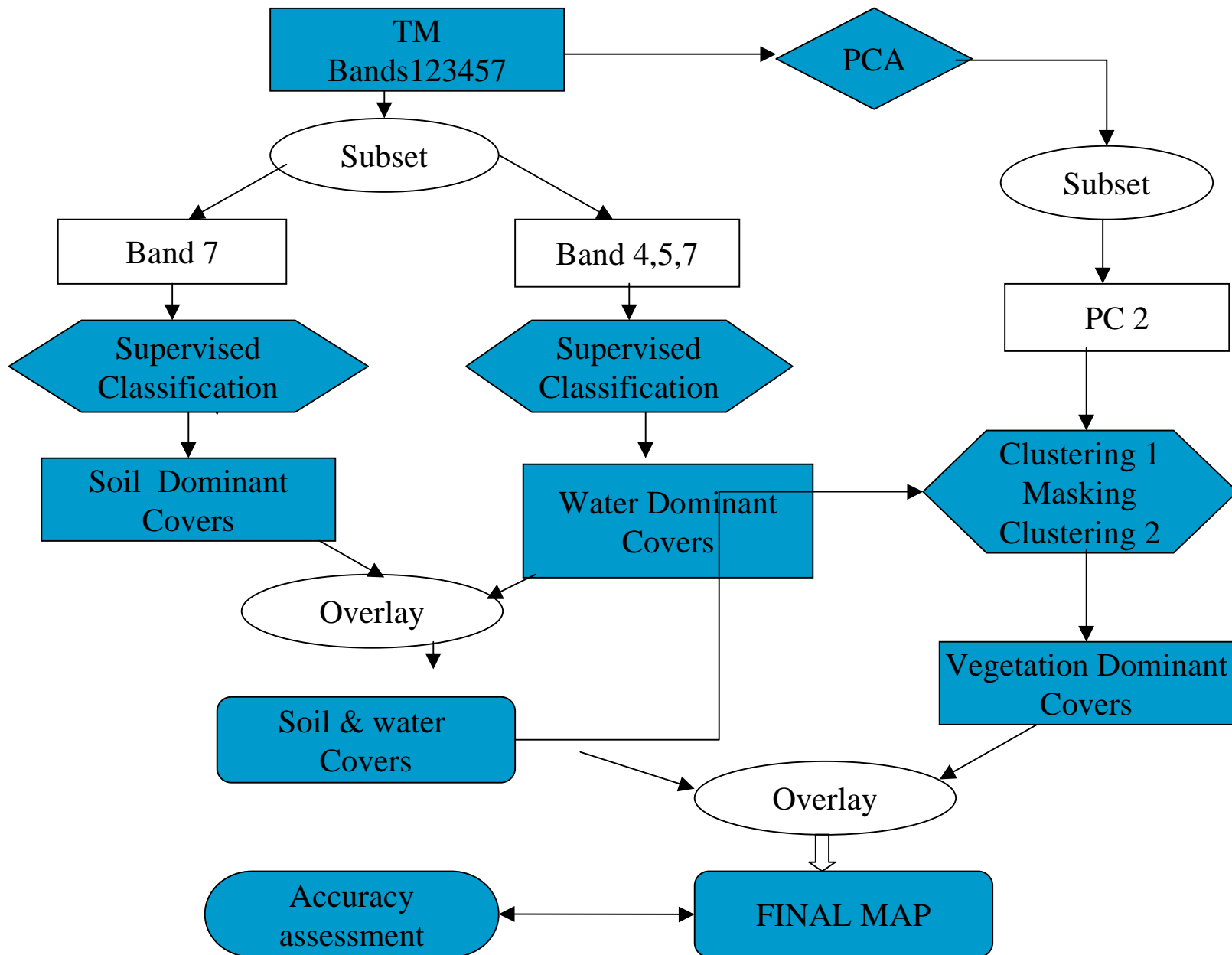


Analyze LUC by these or more categories

*Subsistence Livelihood:  
Market economy model doesn't apply,  
land use intensity driven by population density,  
cultural factors affect density of use/size of tracts.  
Household buying power determines level of inputs*

Stratification of land use sectors: commercial, subsistence (communal) and protected areas

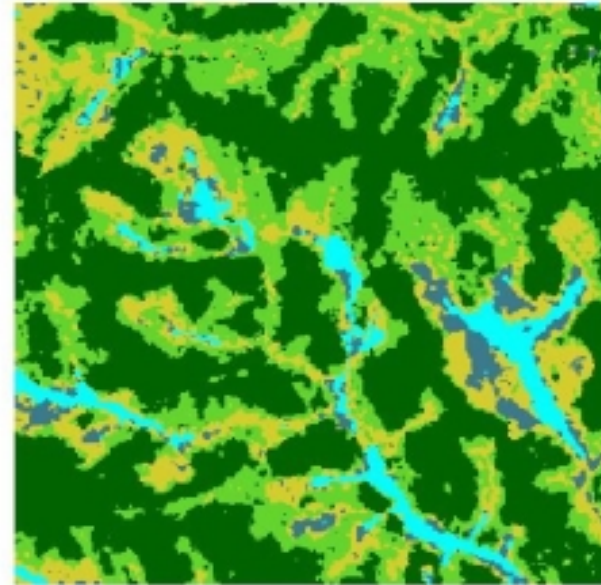
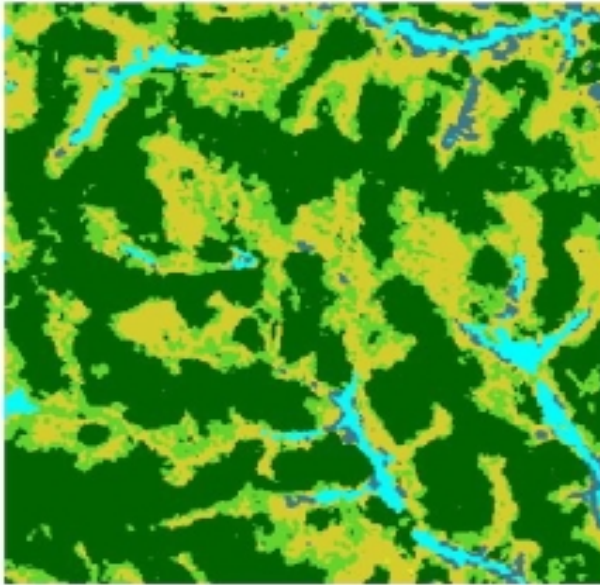




**Flowchart of hybrid supervised-unsupervised classification method used (Jaiteh et al. Submitted)**



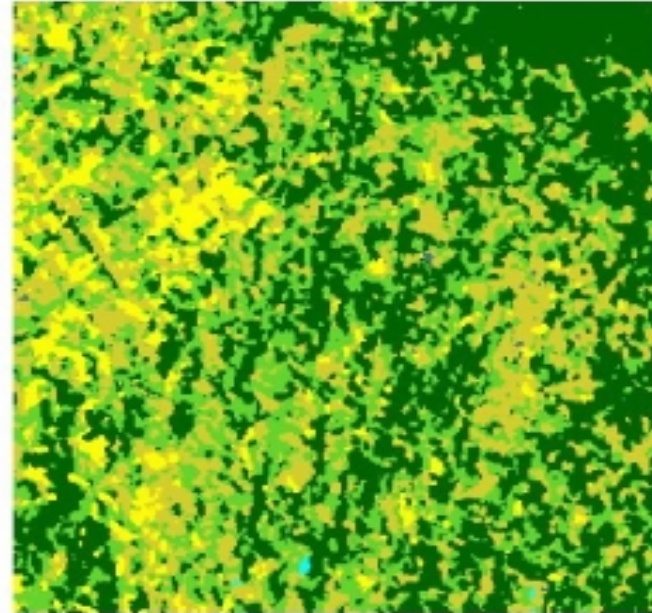
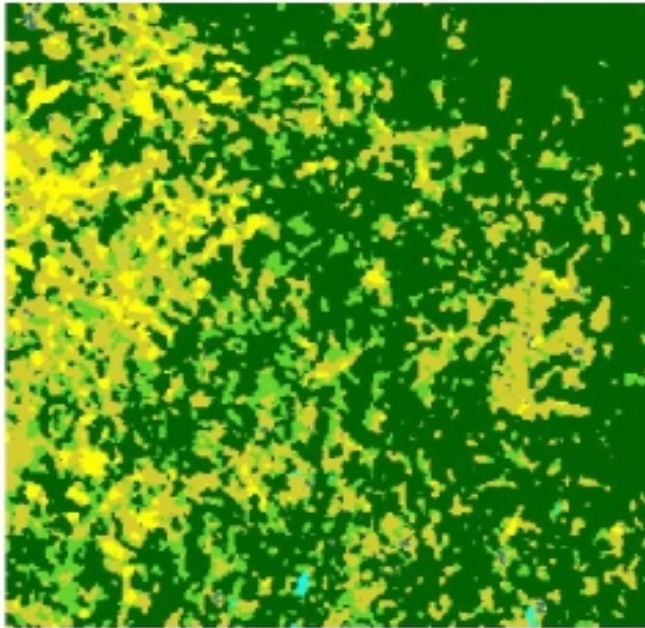
Figure 1. Map showing location of three landscapes in central Malawi, southern Africa. Extensive agriculture in forests (1), intensive agricultural matrix (2) and *Brachystegia* in flat areas (3).



**Figure 2c. Land cover map of Brachystegia in flat area (BFA) landscape. 1984 (top) 1995 (bottom). From Landsat TM data. *Seasonal flooding in dambos and fire scars complicate change analysis***



## *Patterns of Land Cover*



**Land cover map of extensive agriculture in forest area landscape.  
1984 (left) and 1995 (right). From Landsat TM, Kasungu, Malawi**

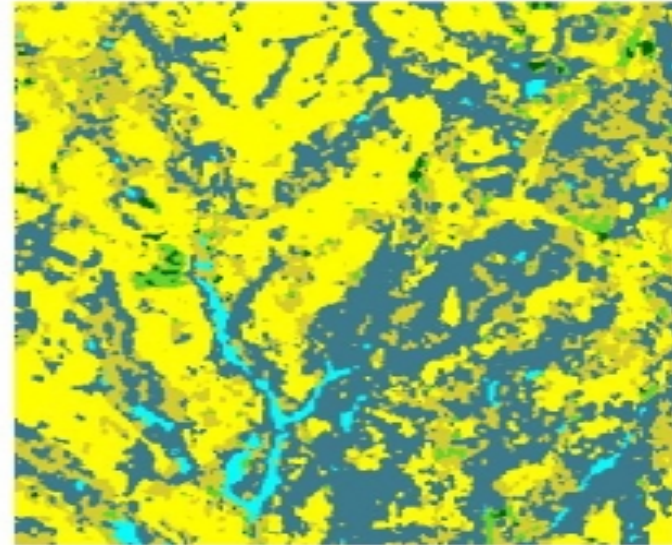
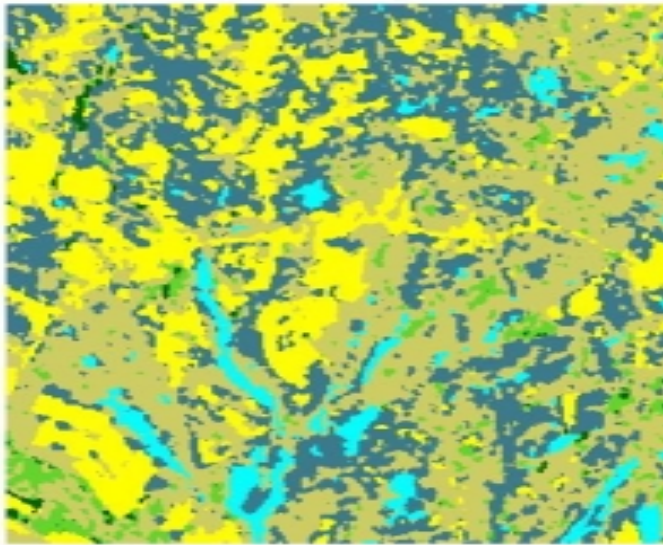


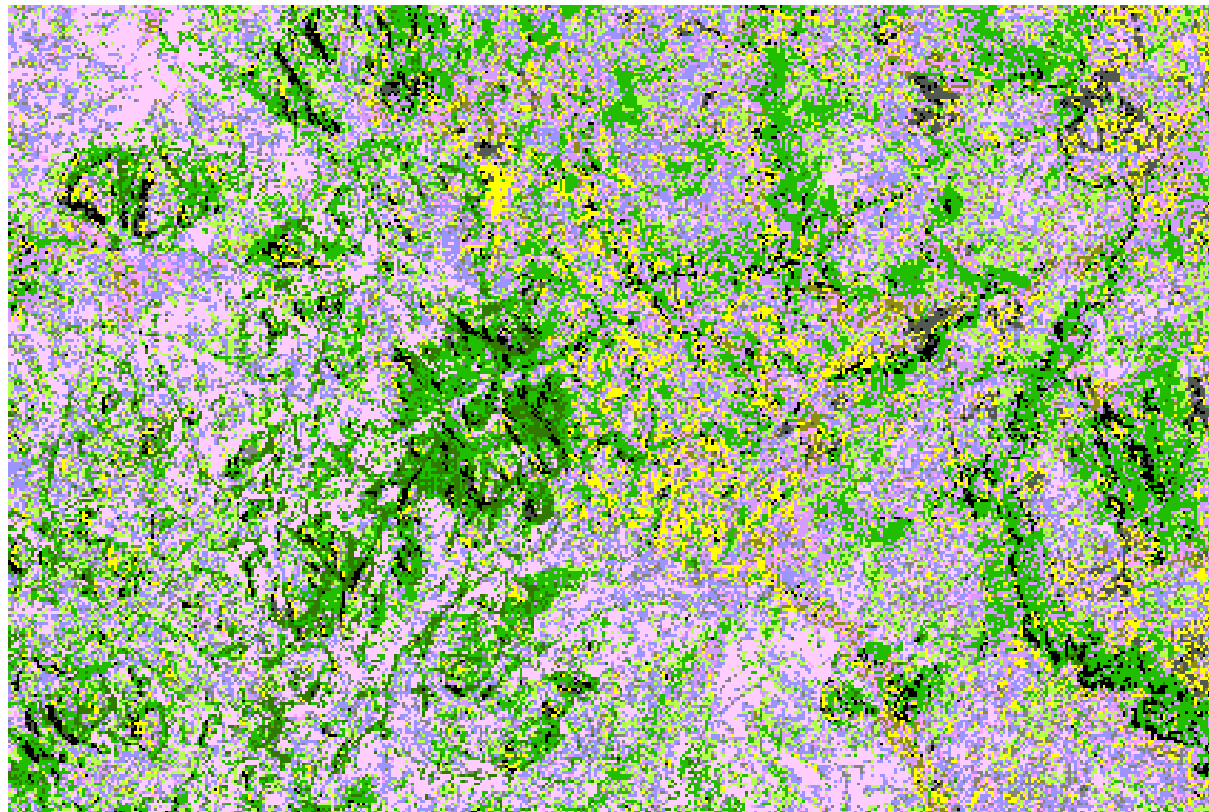
Figure 2b. Land cover map of *intensive agricultural matrix* (IAM) - (commercial farming) landscape. 1984 (left) and 1995 (right). From Landsat TM data for Kasungu, Malawi.

**Table 1. Landscape spatial characteristics for extensive agriculture in forest areas (AFA), intensive agricultural matrix (IAM) and Brachystegia in flat areas (BFA) landscapes**

Landscape indices	Agric. In forest areas		Intensive agric. matrix		Brachystegia in flat areas	
	1984	1995	1984	1995	1984	1995
No. Of patches	74000	86450	75253	74500	39399	35794
Mean patch size (stdev) (ha)	3.5(91)	3.0(24)	4.9(47)	5.0(47)	6.6(66)	7.1(77)
Patch density (#/100ha)	28.48	33.27	20	19.8	15.3	13.9
Largest Patch Index	41	33	37	31	31	32
Edge Density (m/ha)	116.5	156	114	108	91.6	89.5
No. of cover classes	7	7	7	7	7	7
Largest cover type	CW	WG	WG	WG	CW	CW
Percent of landscape area (%)	41	33	37	27	31	32
Percent of woodland cover (%)	52	43	8	11	62	62
Percent of cropland & settlement (%)	3	4	17	27	0	0



### Supervised classification of Murehwa area

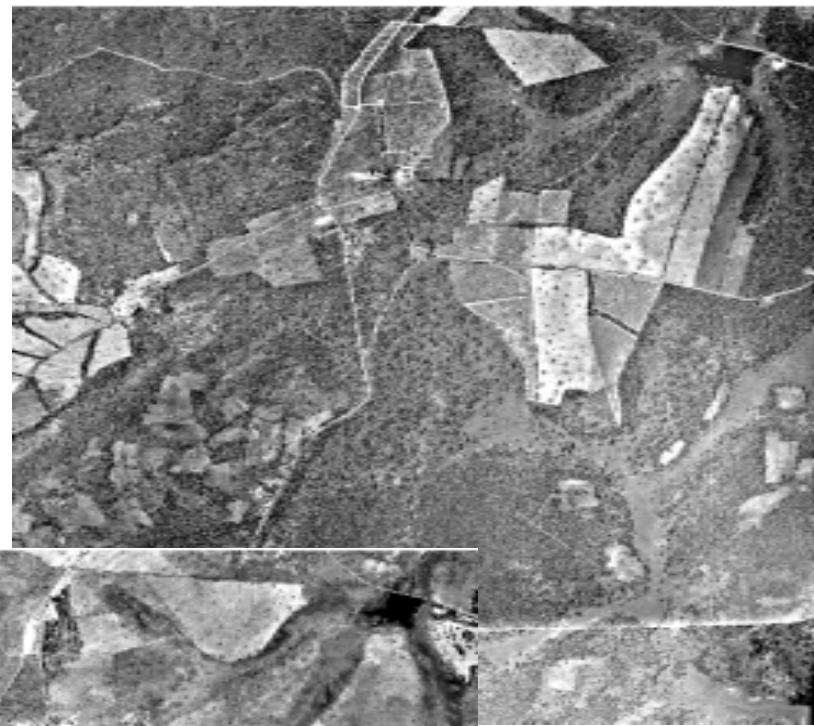


- |   |                            |
|---|----------------------------|
|  | unclassified               |
|  | dambo grassland            |
|  | abandoned land             |
|  | fire scar                  |
|  | shadow                     |
|  | cultivated land (granite)  |
|  | cultivated land (dolerite) |
|  | dense woodland             |
|  | cultivated dambo           |
|  | bare rock                  |
|  | bushland (dolerite)        |
|  | open woodland              |
|  | hill woodland              |

Communal farming area, Zimbabwe - *high levels of fragmentation*, hilly landscape (land less suitable for agriculture)



1964



1976



1995

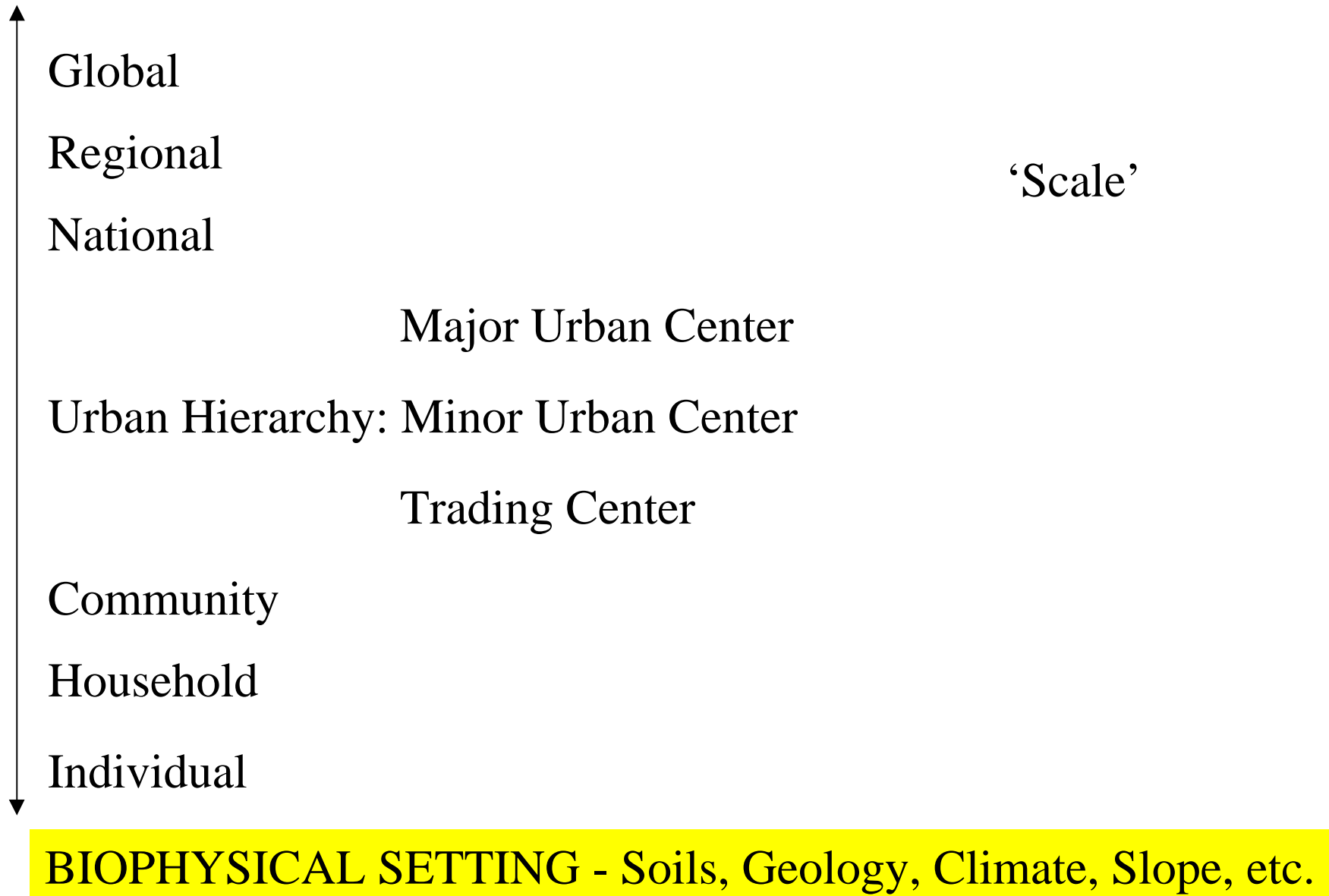
Kasungu APs

**How do we model all this Land Use, given multiple drivers and forcings acting at multiple temporal and spatial scales?**



- 1. Design some structure to the landscape from people to higher levels of organization and spatial interaction**
- 2. Assemble data to represent the relationships**
- 3. Start with a minimal model given data and understanding of inherent scale of processes that are important**
- 4. Complicate model even more**

# HIERARCHICAL LEVELS IN MIOMBO LAND USE MODEL



# Spatial Interactions

- Policy: At National Level, implicit (sometimes explicit) is an implied development paradigm - whether diffusionist (trickle down economics), basic needs, etc.
- For example, Malawi's National Development Plan (1986) implies a diffusionist approach, later development phasing came in with Structural Adjustment Programs, now on to basic needs (poverty alleviation) - driven by global funding
- Other policies include land and trade control policies that have an effect on land use, directly on indirectly



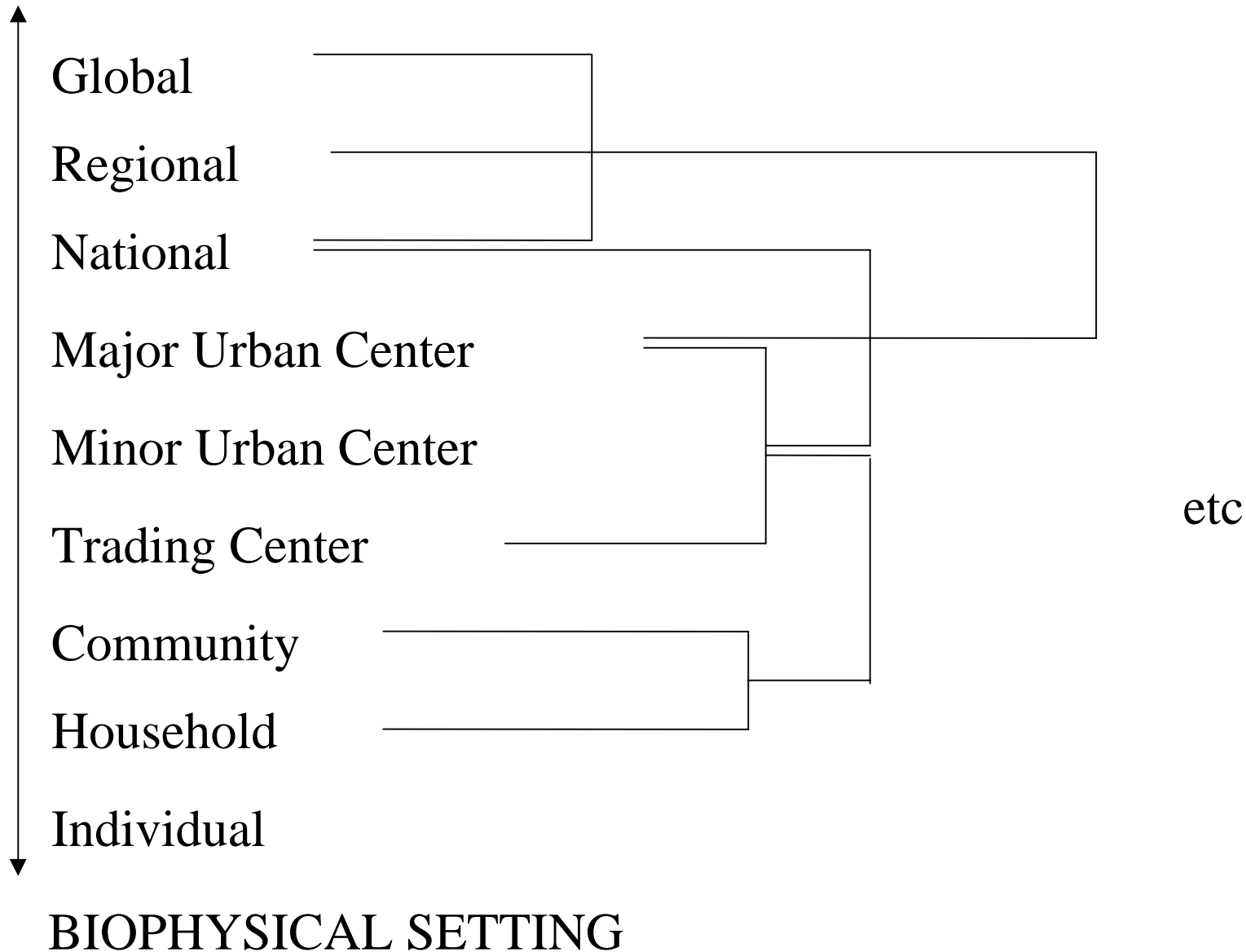
# Between Communities/households and urban hierarchy

- Some mixture of basic needs at household level versus income generation capacity, and some opportunism to move up (function of education, plus other factors)
- Constrained by population density (family size), cultural factors (marriage), geography, etc
- For countries like Malawi, socio-economic data available by Agricultural Development Divisions (and districts) - large databases (one time, not continuous fields)

## **Exploratory Data Analysis - in progress**

- Global to Regional and National - time series analysis (logit regression) to explore strong relationships - develop some distance weights
- ADD or district level - time series analysis (for subsistence and commercial farming systems)
- (Stratifying country into ownership/tenure types)
- For conservation and reserved areas, into managed versus unmanaged (people encroachment then becomes an issue (neighborhood interactions - CA type))

# Linkages/Interactions to be Characterized - from the EDA and literature, other miombo case studies





# Simple Model - Malawi Version

- 3 strata - subsistence, commercial, reserved
- Subsistence: Use trading areas or districts as basic units (these fit into agric develop divisions)
- Predict land use fractions under major land use types (versus pixel specific changes) - prediction function will be a logit function of socio-economic varies (yet to be fitted)
- Commercial: type of activity function of site suitability, national policy, world markets, access to markets/ports
- Unmanaged reserved areas - vegetation dynamics/succession with disturbance (account for bush and human encroachment, fire, herbivory)

## For Zimbabwe ...

- Major strata along Land apportionment - Communal, state land, parks and wildlife, forestry land, commercial (large and small scale)
- Time series of land distribution maps available, including latest resettlements
- Currently developing land cover change vectors for selected sites, and the community-level land use, in conjunction with other projects (CIFOR, etc).
- Tanzania and Mozambique - meetings planned to explore appropriate model structures

# Database Development

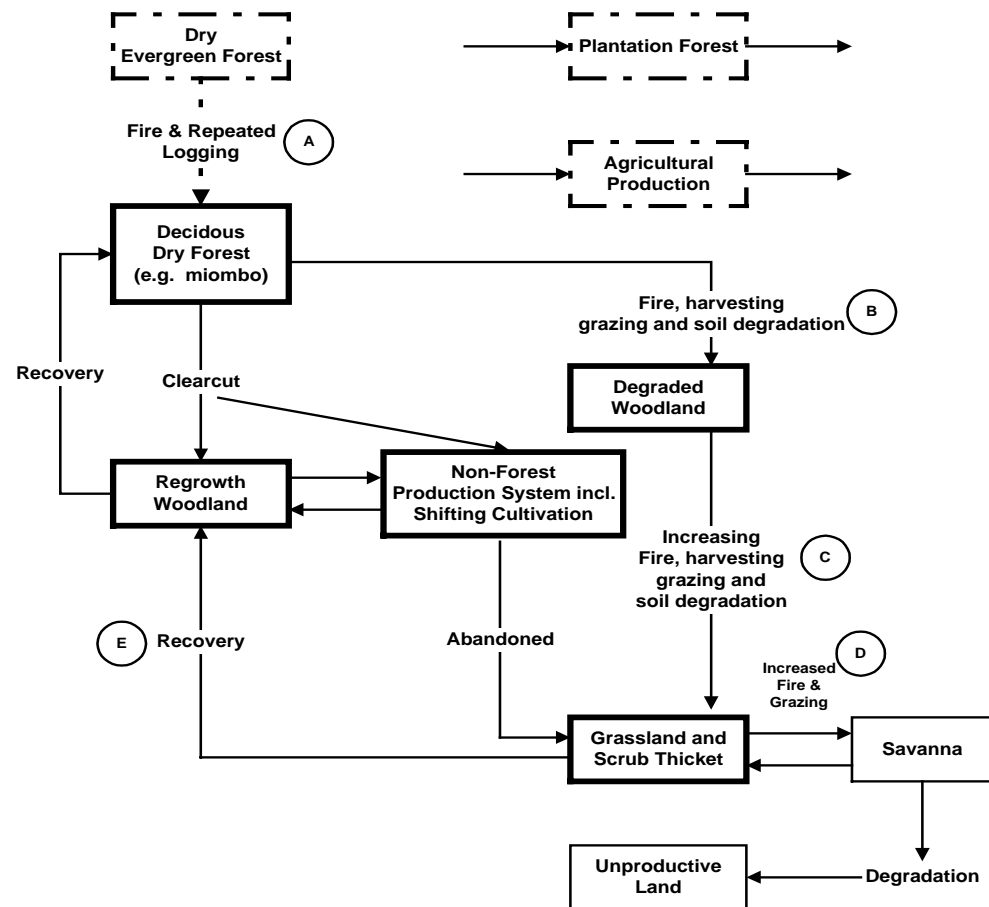
1. Baseline - soils, slope, transportation networks (TS)  
land suitability (f{slope, soils, climate}, various  
boundaries - water bodies, etc (assembled in Miombo CD  
and in followup CD from many sources, e.g. SADC, national  
mapping agencies
2. Climate Data - Climate CD workshop to develop daily  
station time series for further spatial processing to drive  
various modeling - partial drafts available
3. National to Global socio-economic variables - WRI, WB
4. Assembling subnational statistics
5. Baseline land cover/land use (1990/1), harmonizing older  
products as well, future monitoring using Landsat 7 (GOFC)

# Ecological Studies



*Dense Miombo Woodland, Degraded , then Converted to Grassland with Saplings Stunted by Frequent Fires*

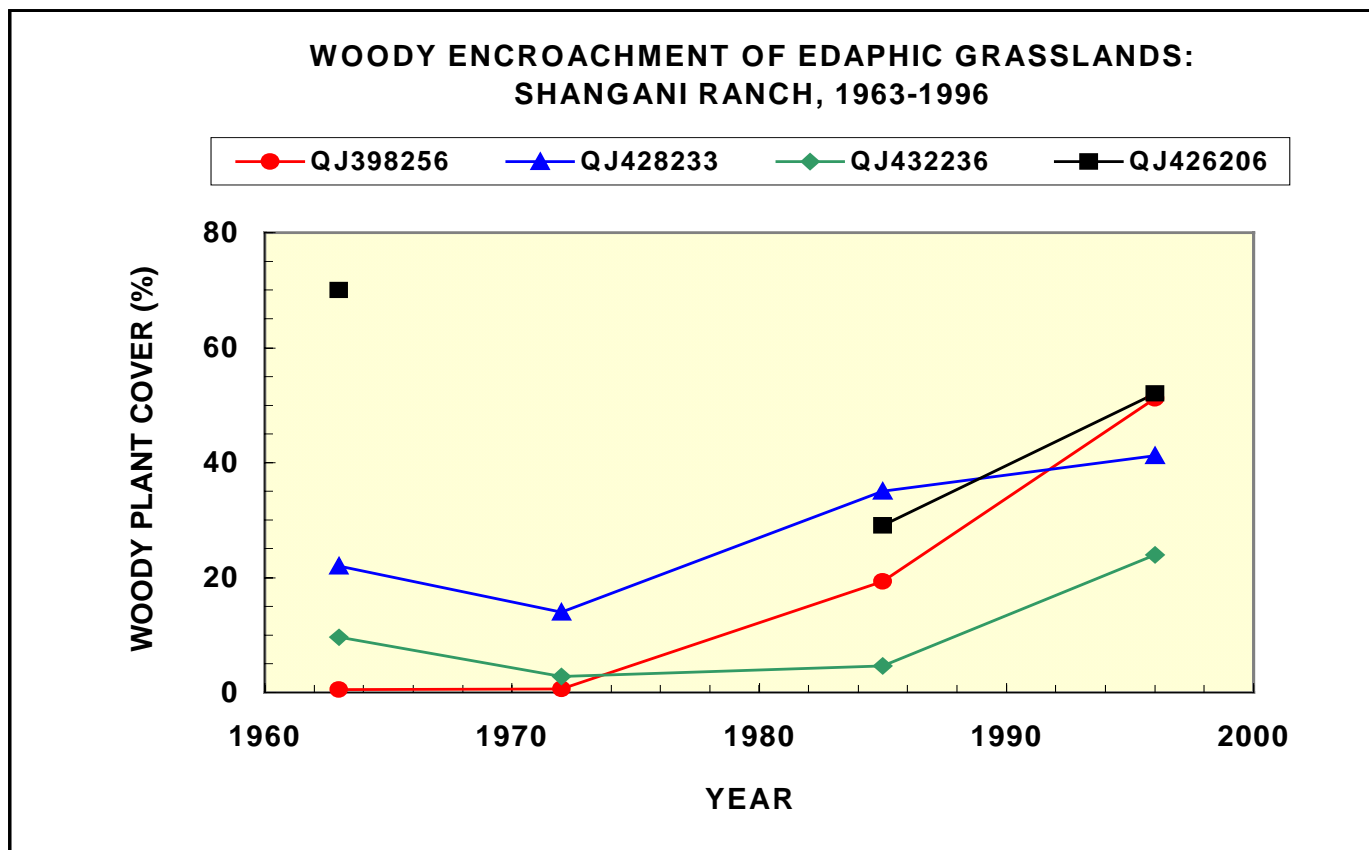




Conceptual model of the effects of disturbances (fire, harvesting/clearing, grazing, etc.) on land cover changes. Emphasis is on miombo woodlands and related transitions, conversions to plantation forest and agriculture are possible at every stage. Letters A-E are major hypotheses to be tested.



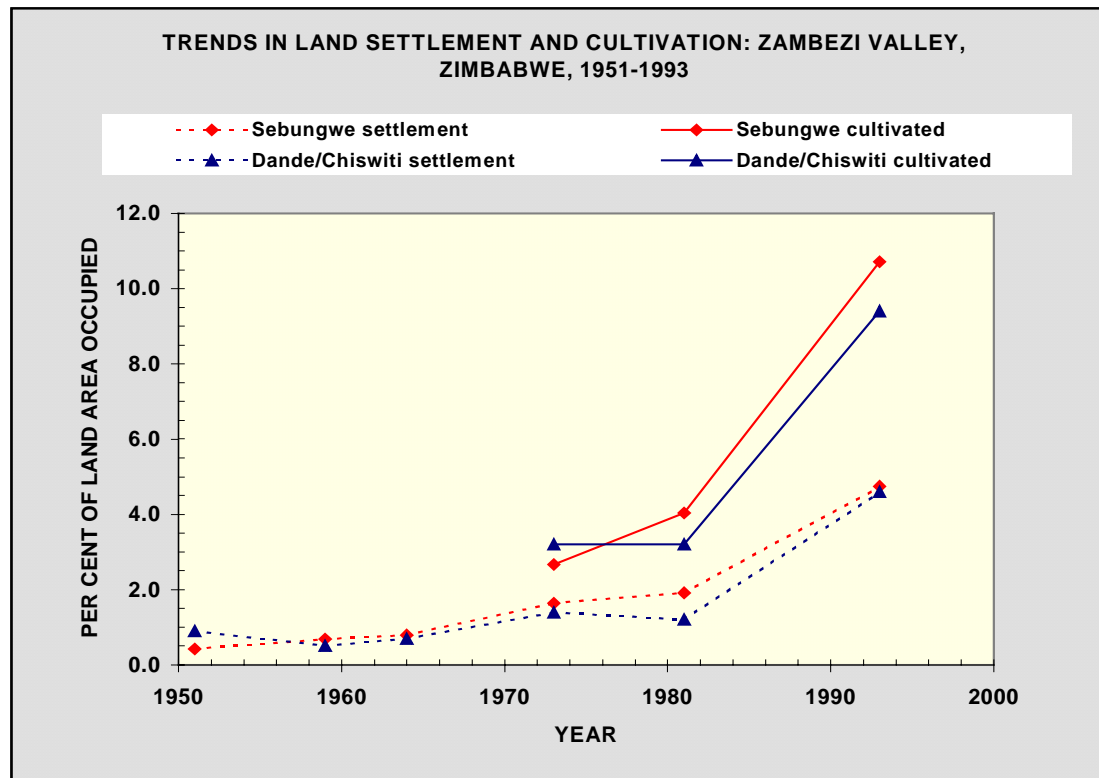
**Encroachment of *Acacia nilotica* on an old field on Shangani Ranch, Zimbabwe. This field was abandoned in the latter part of the period 1963-1972**



**Changes in percentage woody plant cover on four edaphic grasslands on Shangani Ranch, 1963-1996, as estimated from aerial photographs.**

**UTM co-ordinates of the approximate centre of each of the areas sampled are given. No estimate of tree canopy cover was made for location QJ426206 in 1972 as the available aerial photographs did not cover this site.**



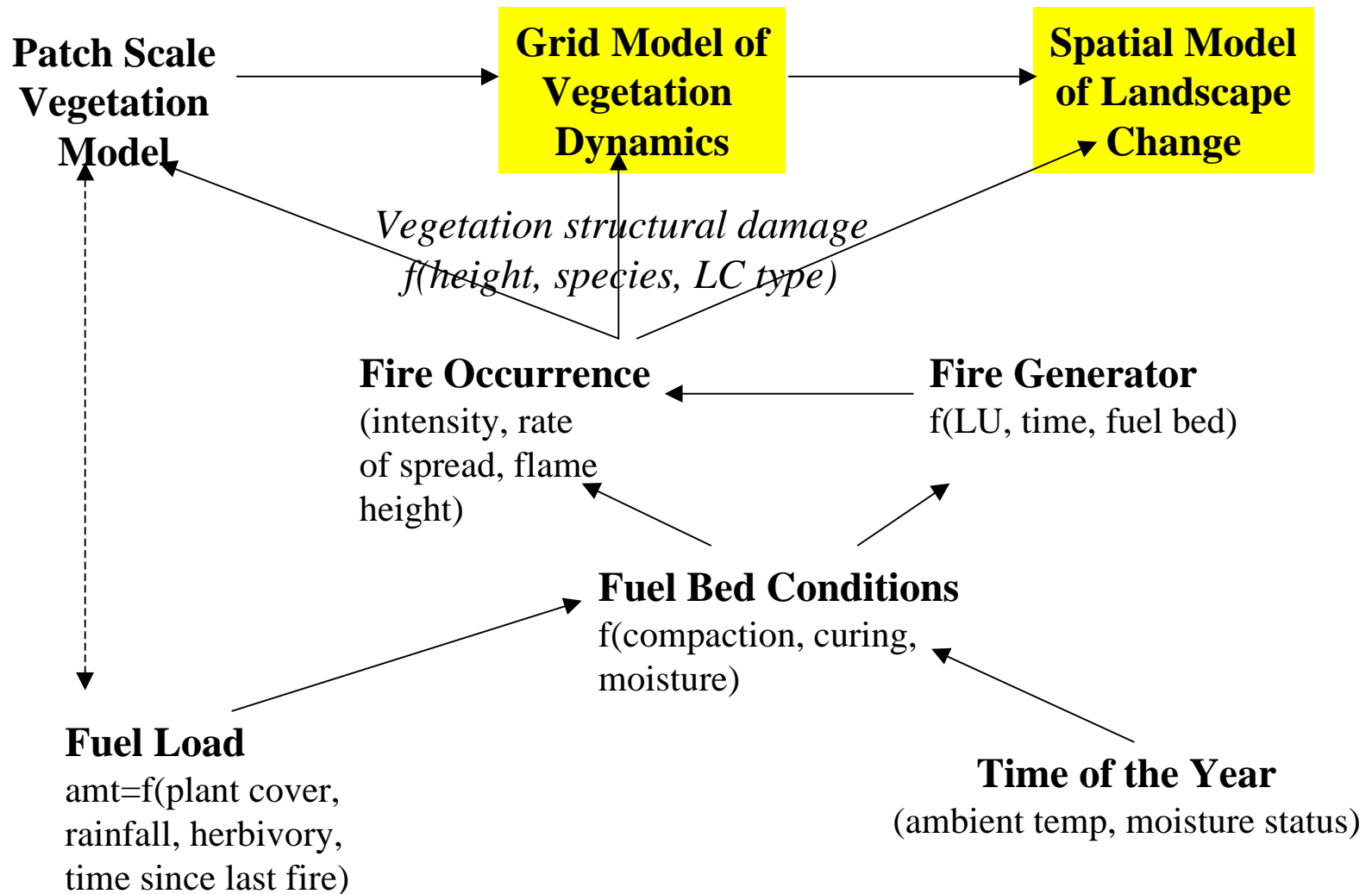


SOURCE: DAVID CUMMING, WWF  
ZIMBABWE

- **CHANGES IN LAND USE AND LAND COVER ARE USUALLY NON-LINEAR AND SOMETIMES DISJUNCT**
- **THESE DATA MAY HIDE CONSIDERABLE TURNOVER IN THE AMOUNT OF LAND ACTUALLY USED IN THE INTERVALS BETWEEN SURVEYS**
- **THE LARGE INCREASE IN CULTIVATED AREA AFTER 1980 IS DUE TO A COMBINATION OF THE END OF WAR, GRADUAL ERADICATION OF TSETSE FLY, INCREASED SETTLEMENT THROUGH IN-MIGRATION, AND EXPANSION OF SMALL-SCALE COTTON PRODUCTION**

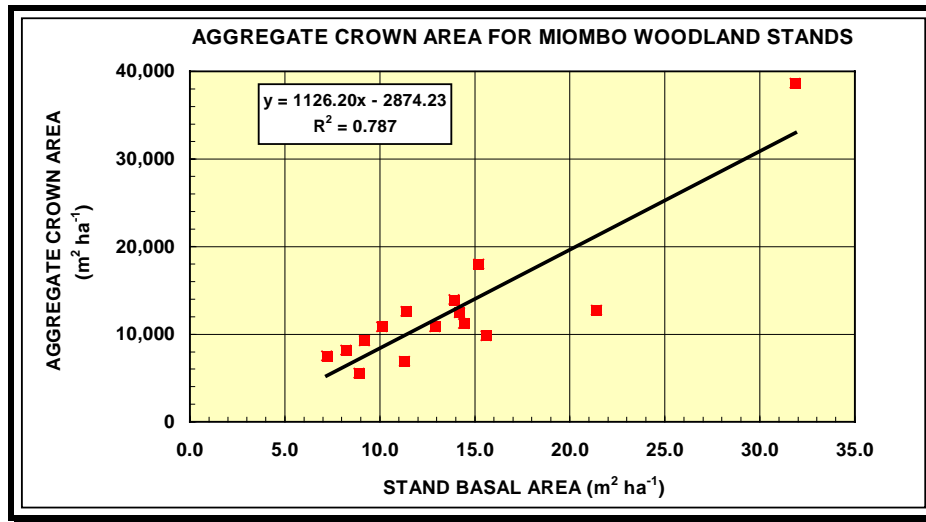
Will link already developed  
patch models to landscape  
level disturbance processes -  
fire, human use, etc

# MIOMBO LU/FIRE MODEL

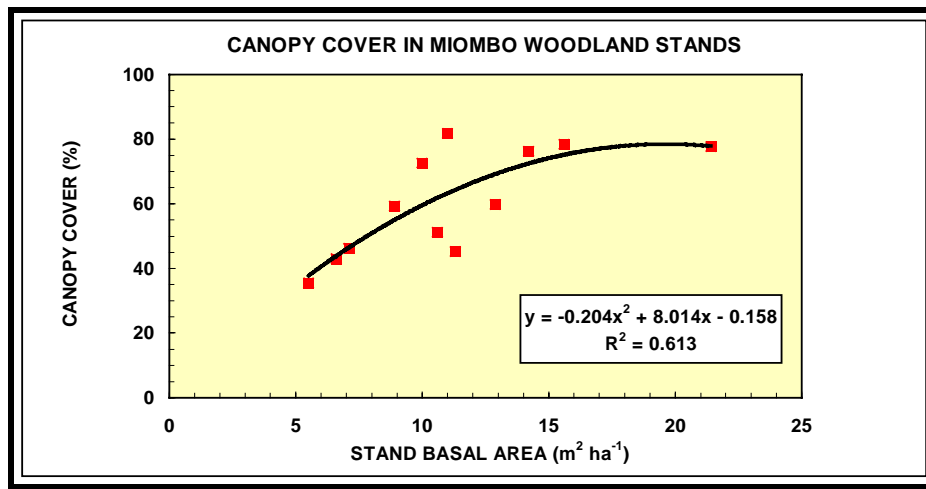


Examples of basic ecological  
relationships that will contribute to  
ecological modeling

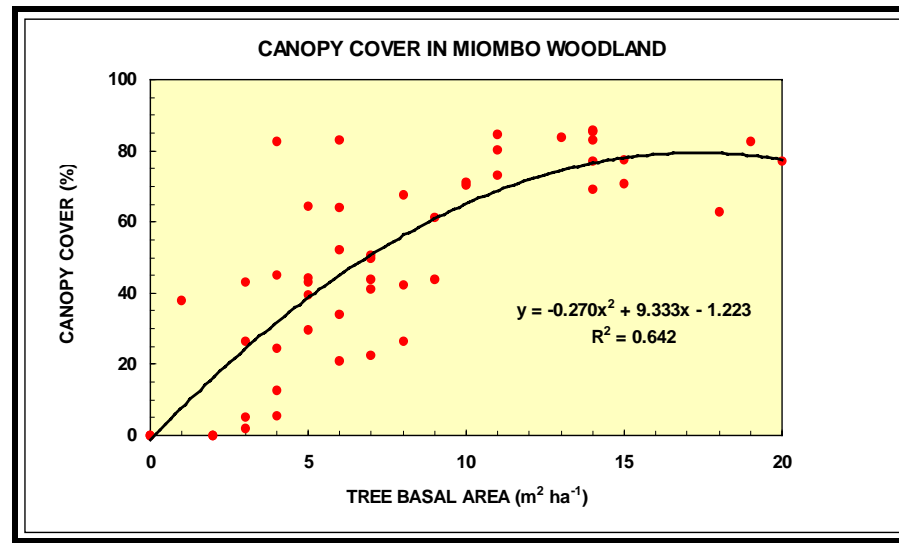




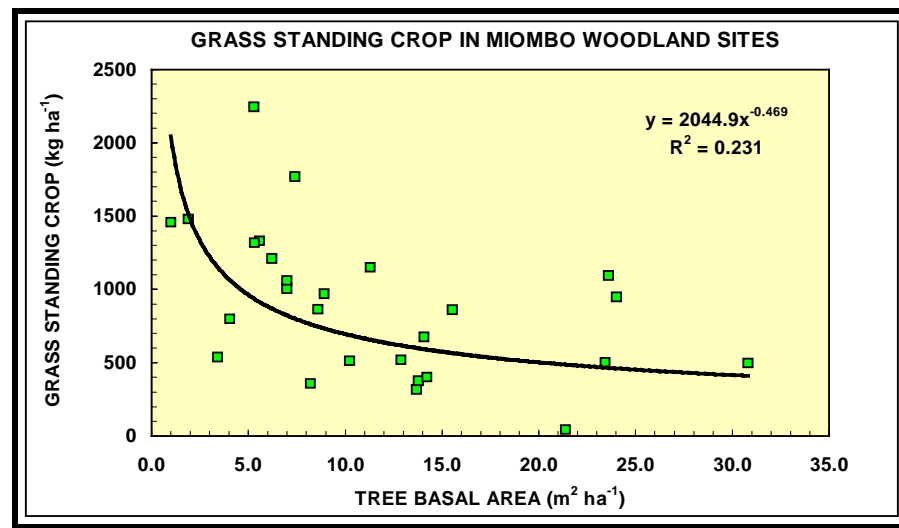
AGGREGATE CROWN AREA INCREASES LINEARLY WITH INCREASING BASAL AREA OF TREES IN THE STAND

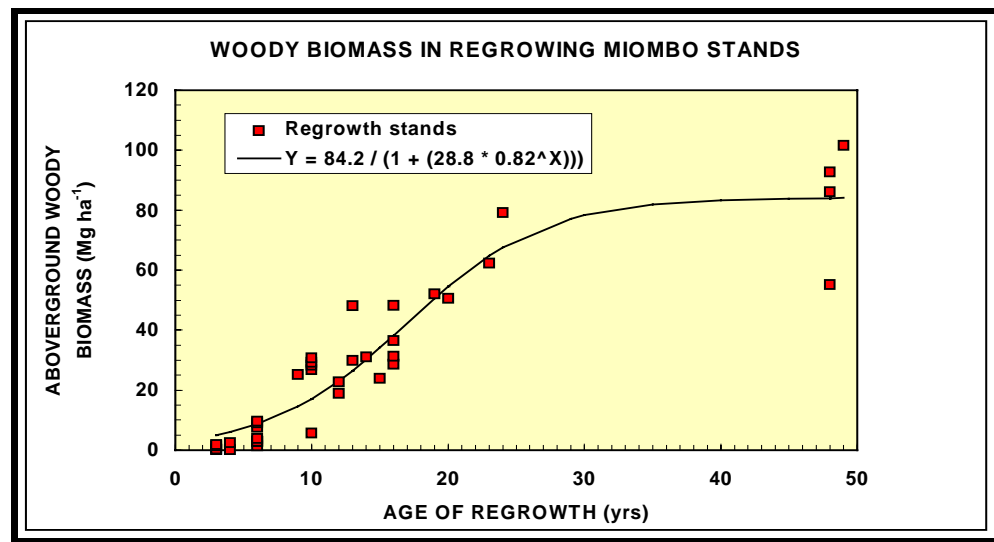
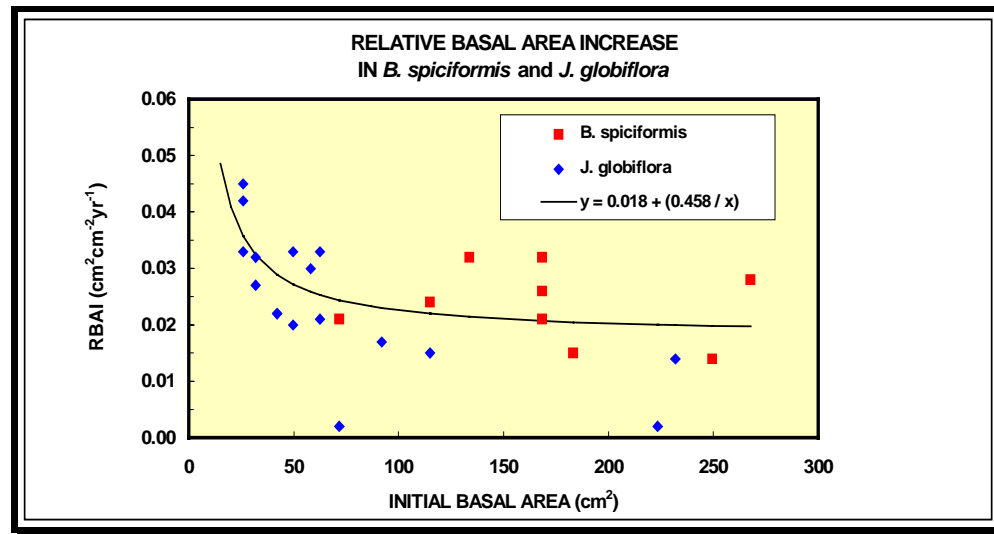


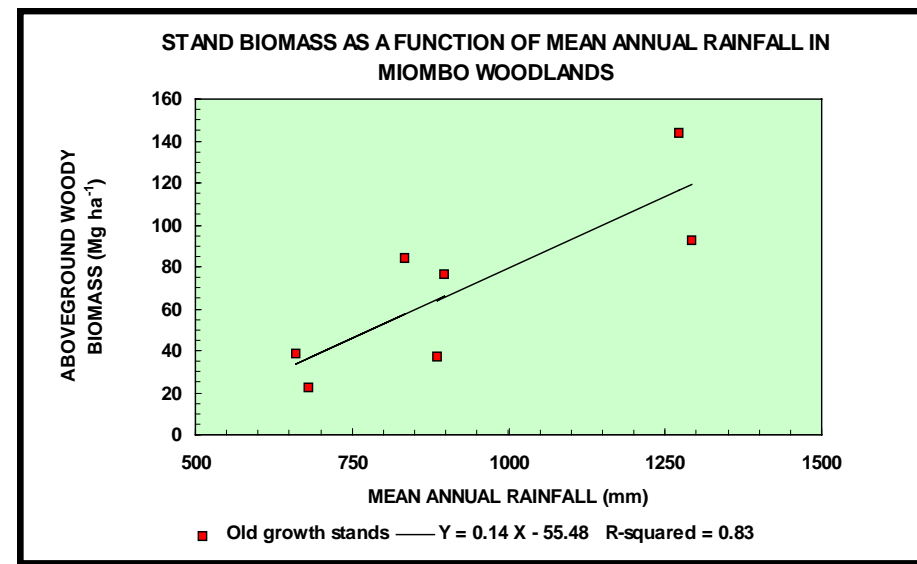
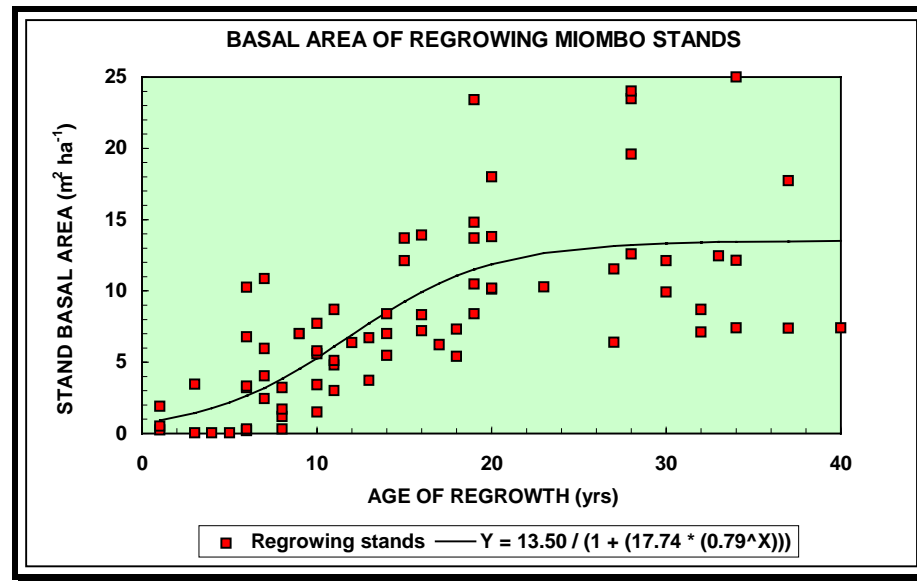
CANOPY COVER INCREASES WITH INCREASING BASAL AREA OF TREES BUT APPEARS TO REACH AN ASYMPTOTE AT ABOUT  $15 \text{ m}^2 \text{ ha}^{-1}$  BASAL AREA



CANOPY COVER WITHIN A STAND IS NON-LINEARLY RELATED TO TREE BIOMASS (INDEXED HERE BY TREE BASAL AREA). AN ASYMPTOTE OF ABOUT 80 % CANOPY COVER IS REACHED AT ABOUT 10-15 m<sup>2</sup> ha<sup>-1</sup>







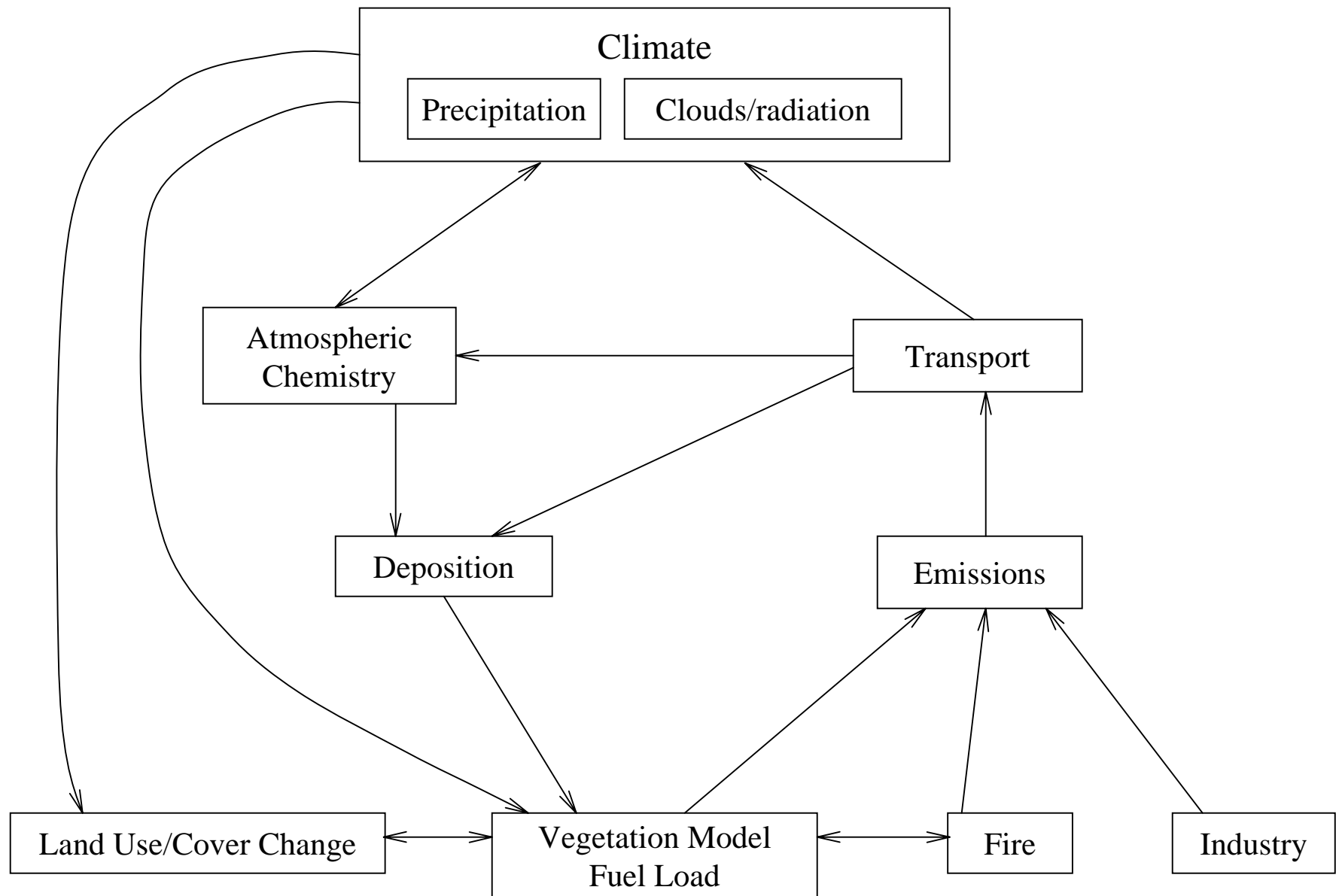


# New Opportunities for Collaboration and Policy Interface

1. SAFARI 2000
2. IPCC - Integrated Assessment; Forestry and Land Use, Assessment Reporting
3. National Policy and Management/Sustainable Development

## CORE ELEMENT 2: LAND COVER AND LAND USE CHANGE (LCLUC)

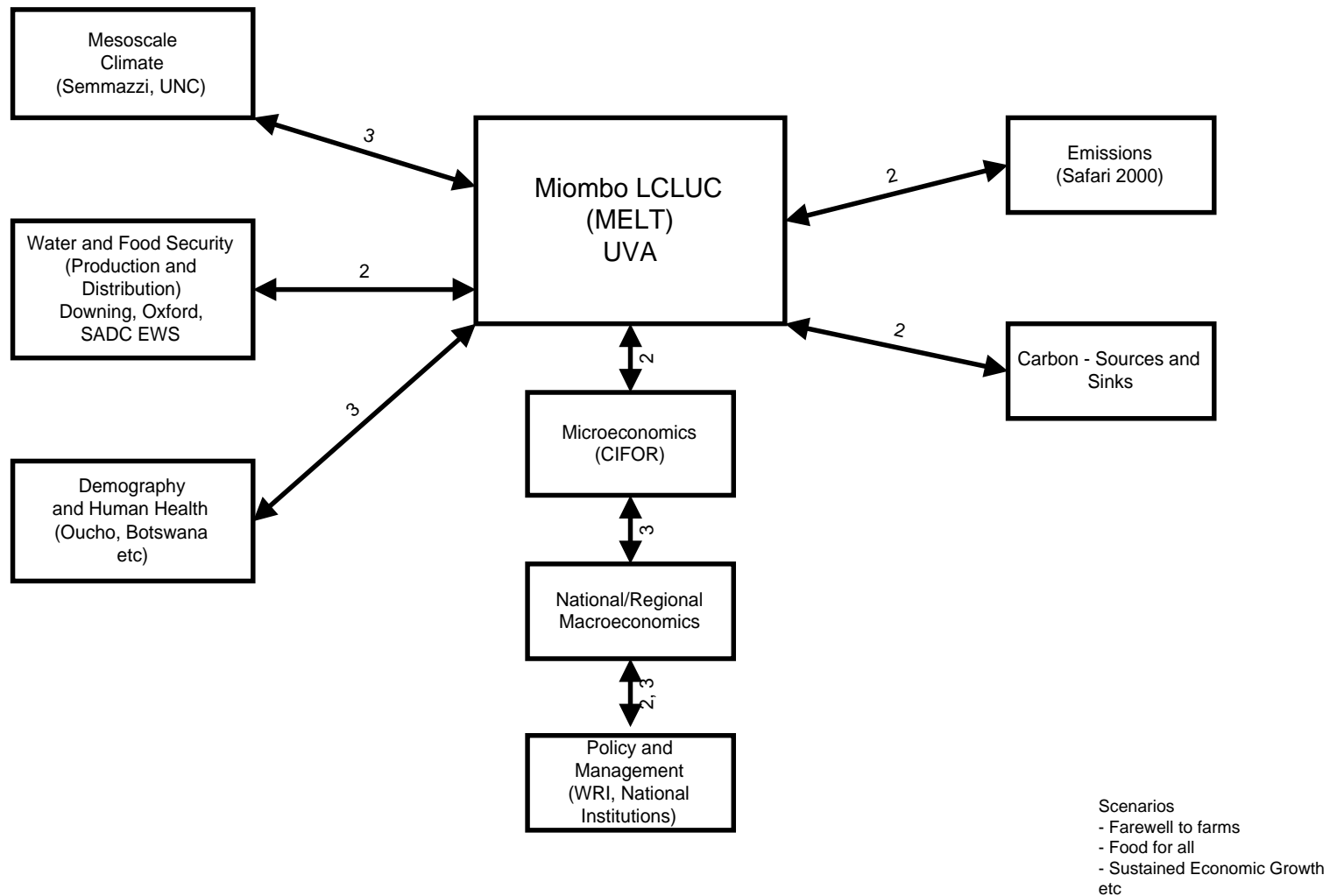
- *Activity 1:* Land Cover and Land Use Change Characterization and their Impacts
- *Activity 2:* Regional Fire Characterization, Emissions and Management
- *Activity 3:* Land Cover-Land Use, Carbon and Emissions
- *Activity 4:* Land Cover and Land Use Modeling
- *Activity 5:* Integrated Modeling of Southern African System  
- Coupling Land Use to Vegetation and Atmospheric Models



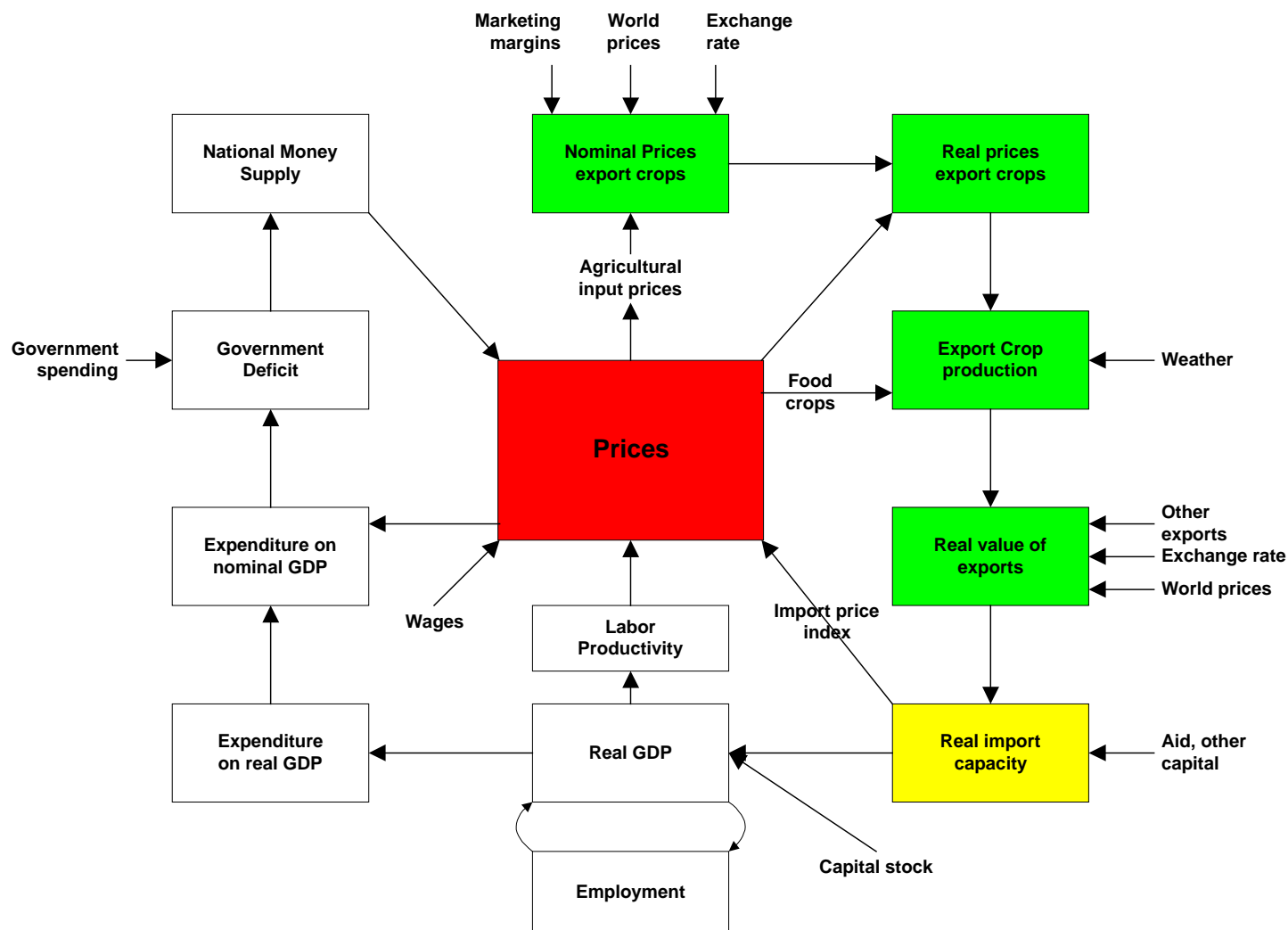
Proposed Integrated  
Modeling Activity - Building  
upon Existing Pieces



## MIMOSA - Mesoscale Integrated Modeling of Southern Africa



# National Level Econometrics



Main Relationships in a Supply Constrained Macroeconometric Model of Tanzanian (after Lipumba et al. 1988).  
Similar implementations exist for Kenya and Botswana.

# Summary of Product Delivery

- Miombo CD - Regional Data
- Baseline data - regional land cover/land use map for 4 countries available using harmonized legend, for 1991;
- Rates of change for few study sites available, more image analysis in progress
- Baseline climate data - 3-6 months, partial drafts available
- First order carbon accounting in progress, ~4 months
- MELT Model (Land Use) - running version for 3/4 countries ~6 months
- Linked Vegetation-Fire-Land Use model ~1 year

# The Miombo CD Project

The first Miombo Network meeting in Zomba, Malawi December 1995 identified data availability as a major constraint for development of a strong scientific agenda, and in general, for global environmental change research in Central and Southern Africa (funded by NSF, IGBP)

The Miombo CD project was then designed to make data widely available to Miombo Network Projects and more generally, to regional scientists (funded by NASA, START, IGBP DIS).

Data were collated from various international data archives and from individuals, and processed to be accessible using a web browser on a cd-rom.

The Miombo CD contains all the software required to access and manipulate the data, including a GIS, a Web Browser, Adobe Acrobat Reader and utilities for converting the GIS data commonly used Arc/Info export format and IDRISI image format.



MIOMBO  
NETWORK



LAND USE AND  
COVER CHANGE

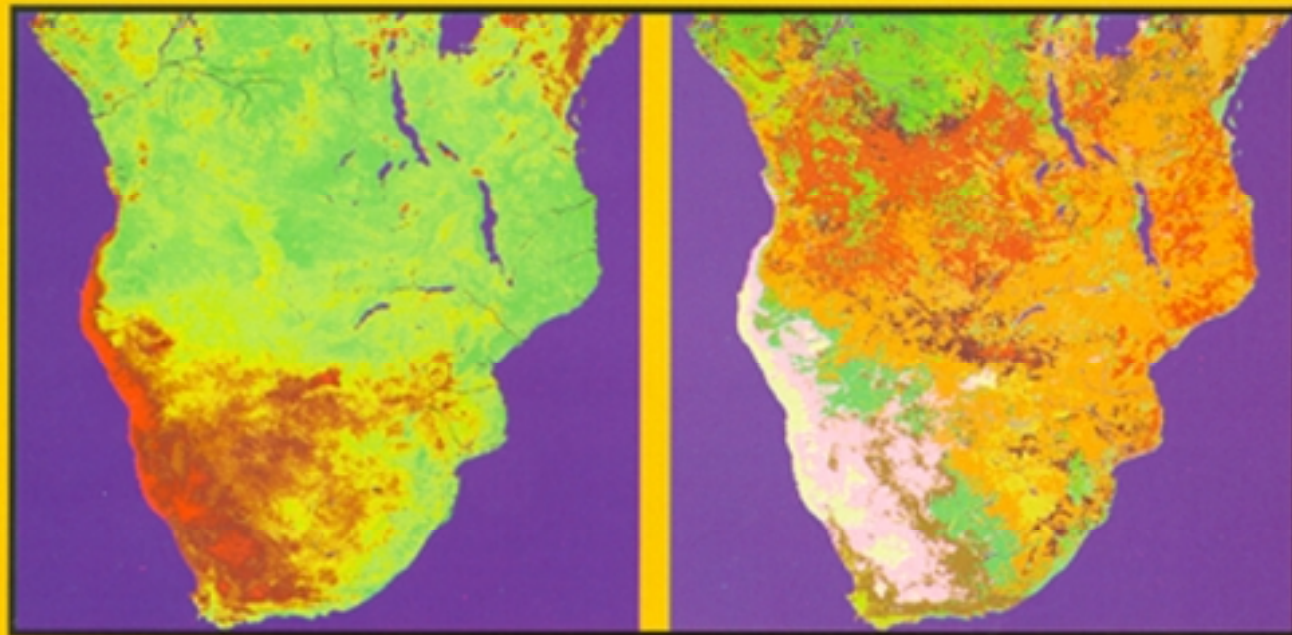


IGBP DIS



IHDP • IGBP • WCRP

# LUCC CD-ROM Series. N° 1: MIOMBO



Also sponsored by:



Mission to Planet Earth  
National Aeronautics and Space Administration



Generalitat de Catalunya  
Institut Cartogràfic de Catalunya







START/SADC Climate Data Workshop Report - Microsoft Internet Explorer

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**START/SADC Climate Data CD-ROM Workshop**  
Harare, Zimbabwe April 19-23 1999

### Workshop Report

**Location:** Harare, Zimbabwe  
**Date:** April 19-23 1999  
**Hosts:** SADC Regional Remote Sensing Unit  
SADC National Meteorological Services  
Zimbabwe Forestry Commission

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<a href="#">Modeling Needs in Africa</a>	<ul style="list-style-type: none"><li>• <b>State of Data Management in Governmental Data Centers</b> <a href="#">Botswana</a>, <a href="#">Malawi</a>, <a href="#">Mozambique</a>, <a href="#">Namibia</a>, <a href="#">Tanzania</a>, <a href="#">Zambia</a>, <a href="#">Zimbabwe</a></li></ul>
<a href="#">Currently Available Datasets</a>	<ul style="list-style-type: none"><li>• <b>List of Data CD-ROMs produced</b> Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, Zimbabwe</li></ul>
<a href="#">Meeting Agenda</a>	
<a href="#">Participants List</a>	

GECP Africa, ,University of Virginia, 1999

Start Re: Africa Expert Meeting I... Exploring - Airle START/SADC Climat... Microsoft PowerPoint - [Mi... My Computer 11:32 AM

# Mid-life Crises or Project Course Corrections

- Fast track shift from case study sites to regional extent - in response to immediate needs for consistent baseline data (Safari 2000, IPCC IAM, etc); and large number of related 'pieces' from Miombo Network partners - need for integration and synthesis great
- Renewed emphasis on fire - Peter's talk later
- Potential for very exciting new data sets through GOFCLandsat 7 and other instruments, need to be ready to take full advantage

Integration into LCLUC  
model Challenging -  
broadening inputs to include  
diverse **experts** in attempting  
to develop a “good” LUCCy  
model (with socio-economic  
and ecological components)